THE DIVISION OF FLUID DYNAMICS
of the
AMERICAN PHYSICAL SOCIETY

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(Remarks at the Cambridge Meeting, June 17, 1949)

On June 28, 1946 E. U. Condon, then president of the American Physical Society, appointed a Committee on Fluid Dynamics to organize a program on fluid dynamics at the January 1947 meeting of the Society and to consider the type of organization that would insure the permanent consideration of fluid dynamics by physicists. The leading spirit in the discussions with reference to the appointment of this committee was R. J. Seeger, a physicist who had become interested in fluid dynamics as a result of his wartime work. The committee named was R. J. Seeger, Chairman, J. von Neumann, Th. von Karman, H. L. Dryden, and H. W. Emmons.

At the New York meeting on January 31 and February 1, 1947, one session was devoted to a symposium on recent developments in compressible flow, two sessions of invited papers presented important experimental and theoretical work on shock waves, water entry phenomena, and compressible flow, and numerous papers were contributed to other sessions without individual solicitation. There was a brief discussion following one of the sessions of the desirability of forming a Division of Fluid Dynamics. The proposal met with favor. The committee was requested to proceed with the formation of the Division and the necessary petition to the Council was signed. About 250 members expressed interest.

At the New York meeting in January 1948 arrangements were made to hold joint sessions with the Institute of the Aeronautical Sciences. Programs were presented on problems related to the upper atmosphere and the physics of rarefied gases. At this meeting the Council approved the formation of the Division and approved the proposed by-laws. The Committee on Fluid Dynamics recommended that President Oppenheimer appoint a special Nominating Committee to conduct immediately the election of the officers of the Division, and that the committee itself be continued in office as an organizing committee until the election had been completed. These actions were taken by the president, and the election was conducted by the Nominating Committee: W. Bleakney, F. H. Clauser, and G. E. Uhlenback.

R. J. Seeger (1950)was elected chairman, H. W. Emmons (1948)-secretary, and H. L. Dryden (1949), J. W. Beams (1948), P. S. Epstein (1950), J. G, Kirkwood (1950), Th. von Karman (1948) members of the executive committee, the terms expiring as indicated.

At the New York meeting in January 1949 joint sessions with the Institute of the Aeronautical Sciences were again arranged. The special features were a symposium on turbulence extending over two sessions and two additional sessions of invited papers. The elections resulted in the present executive committee: H. L. Dryden (1950), chairman, J. G. Kirkwood (1950), vice chairman, Walker Bleakney (1949), secretary-treasurer, R. J. Seeger (1949), P. S. Epstein (1950), Liepmann (1951), Kantrowitz (1951).

The first meeting of the Fluid Dynamics Division alone will be held on June 30 and July 1, 1949, at the Naval Ordnance Laboratory, White Oak, Maryland, with symposia on aerothermodynamics, shock-wave phenomena, and turbulence and sessions of contributed papers. As customary with meetings of the American Physical Society, the number of contributed papers is so large as to sorely tax the available meeting rooms.

A second meeting devoted to the physics of gas flows with heat addition, transport of matter, momentum, and energy, and/or chemical reaction (including combustion) is planned for the Christmas holidays at the University of Virginia. The program is being planned by J. Hirschfelder, B. Hicks, J. G. Kirkwood, B. Lewis, and J. W. Beams.

So much for the purely organizational aspects and calendar of meetings. I assume that your principal interest is to gain some impression of the scientific problems discussed at our meetings. My principal interest is to indicate that there are stimulating and important problems in fluid dynamics which should receive greater attention from the most capable physicists.

One of the areas in which I personally have been greatly interested is that of the turbulent motion of fluids. As most of you know, the direct application of the classical Newtonian laws of motion as adapted to an incompressible continuum, whose known non-continuous structure is taken into account only on a macroscopic scale by the use of the concepts of density and viscosity, leads to the Navier-Stokes equations for which the general solution has not yet been found by the mathematicians. Particular solutions have been found for certain simple boundary conditions, i.e. flow in an infinitely long cylindrical pipe, flow in a boundary layer, etc. These particular solutions yield a steady flow in layers, the so-called laminar flow. Under some conditions such flows are found in nature; under most conditions the flow varies rapidly with time and with a certain aspect of randomness. This flow we call turbulent. Its characteristics are not fully understood; there is no general theory, and experimental information is incomplete. Even the best concepts for its description have not yet been discovered.

As physicists, we may take various points of view. We may blame the lack of knowledge and place the full responsibility on the mathematicians. The turbulent flow simply represents other possible solutions of the Navier-Stokes equations satisfying the boundary conditions which the mathematicians haven't yet found. The question of what type of flow is to be found in any actual case is a mere matter of stability as regards slight disturbances which can be described by still more complex mathematical equations. No questions of physical theory are involved, and there is no need for physicists to study the problem.

Such an abdication of responsibility would restrict physics to theoretical physics of very narrow scope. I conceive the responsibility of physics to be not only to provide the fundamental concepts and general theory for describing the physical world around us but also to provide the experimental tools and measurements to indicate which concepts and theories are most useful in describing and understanding physical phenomena. While some physicists specialize in theory and are almost pure mathematicians and others specialize in experiment and are almost pure engineers (if an engineer can be pure) but call themselves applied physicists, the ideal type of physicist is constantly attempting to drive a double team of theory and experiments, striving to keep the two more or less in step.

Hence the physicist looking at the problem of the turbulent motion of fluids should feel a responsibility for inventing new concepts and refining old ones, creating new idealized pictures for experimental and theoretical investigation, devising new methods of measuring quantities corresponding to these concepts and hypotheses, and attempting to analyze and understand the phenomena in greater detail. Let us look at a recent contribution of a physicist, W. Heisenberg, fortunately for turbulence research forcibly diverted from nuclear research and compelled to seek new interests. Before his current papers on this subject, the feeling was fairly general that the "normal" type of fluid motion was the laminar one, represented by the particular solution of the Navier-Stokes equations. This steady motion was obviously the one to be expected. As the Reynolds number (reference speed times reference dimension divided by kinematic viscosity) became larger, this motion became unstable. This view is a very plausible one; there is now in fact a body of theoretical and experimental data which gives a beautiful picture of the instability of a laminar boundary layer. This work was described at one of the recent meetings of the Fluid Dynamics Division. Insofar as it goes, this description of the origin of turbulence is correct. Now view the same physical systems through the eyes of Heisenberg, a nuclear physicist, to whom the "natural" state of a system to which energy is imparted is an "excited" state. To him a mass of fluid is a system with infinitely many degrees of freedom. It is not surprising to him that the flow varies with time; he expects the energy to be distributed among the many degress of freedom of the system. The surprising thing to him is that there is a motion with no energy in the many modes, and he seeks rather to explain the laminar motion.

I have not time to review the full picture developed by Heisenberg, Onsager, and others, of the concept of a spectrum of energy fed at the longer wave length and by the separation of flow and regular eddying motions determined by the geometry of the apparatus, the energy passes through a cascade of eddies of smaller and smaller wave length as a quasi-stationary process, until at the short wave length and the dissipation action of viscosity makes its influence felt sufficiently to rapidly reduce the energy at high frequencies. With certain assumptions, this theory can be given quantitative form and subjected to experimental check.

In addition to this reoriented point of view, Heisenberg and Onsager pointed out that the experimental methods then in use gave a distorted picture of the spectrum, since they were based on one-dimensional rather than three-dimensional considerations. Unfortunately, the relation between the two involves a double differentiation of the one-dimensional spectrum and no method has yet been found for direct measurement of the three-dimensional spectrum.

There are many more puzzling questions in turbulent fluid motion, in particular, the exact source of the randomness and the nature of the statistics which describes the energy distribution in the different modes. I think I have said enough to indicate that physicists can find challenging problems and can make significant contributions.

A second topic that you find frequently in our programs is that of shock waves. Here again most of you know that a compressible fluid moving at supersonic speeds, i.e., faster than the speed of compression waves expands in a manner predictable by the classical theory, but that attempts to obtain compression by the reverse process fail because of the appearance of shock waves. These are almost discontinuous changes of pressure, temperature, and velocity that occur in a distance often comparable with the mean free path. Hence, one topic is whether shock waves can be treated by continuum theory and whether their appearance is associated with the fact that the fluid is not a continuum. There is still no theory as to what really gives rise to the presence of shock waves; there are only studies of the compatibility of the existence of discontinuities with the general equations of motion and the boundary conditions, when entropy changes are assumed at the shock wave.

The refreshing influence of the work of physicists in this area may be illustrated by the work of Ladenburg and Bleakney at Princeton. Much paper and pencil work and computing machine effort has been expended on the problem of the triple intersection of three shock waves. A single excellent interferogram of such an intersection (~~recently~~ published in the ~~Journal of Applied Physics~~) shows that most of this effort is fruitless, since the assumption of uniform pressure, temperature, and velocity behind each shock wave is shown to be correct for only two of the three waves. With a sufficient number and variety of experiments to guide the theoretical work, we may hope to better understand what takes place.

The relation of shock waves to acoustic waves, the laws of decay of shock waves, their interaction with acoustic waves and with each other, all are areas where there is much theory and talk but little knowledge. The interaction of shock waves and boundary layers, laminar or turbulent, is a highly interesting field which can only be studied fruitfully by physicists and only a few physicists of sufficient background in fluid dynamics are working on the problem.

The physics of moving rarefied gases is another area with many problems. In particular, the relations between a gas regarded as an aggregate of moving molecules and the same gas as a continuum give many areas for doctors' theses and mature effort. Flow in the "slip" region where neither description is adequate is one of the frontiers of physics today. I will only mention the contribution to experimental techniques of flow visualization which arose from a suggestion of J. Kaplan and which is on the program of this meeting. The use of the afterglow of nitrogen as an indicator of density changes makes possible the visualization of shock waves and flow separations at densities measured in microns of mercury.

Phenomena associated with changes of state such as condensation of water vapor, carbon dioxide, etc. in the flow of gases at extremely high speeds are promising targets of the physicist. Relaxation phenomena in the distribution of energy among the molecular degrees of freedom must be considered.

Problems of aerothermodynamics involving heat addition, combustion, heat transfer in high-speed gas streams, transport processes, water entry problems, cavitation, flow through porous materials - these and many other problems might be described in much more detail. But time will not permit.

At present the Journal of Applied Physics is publishing about 15 articles per year in the field of fluid dynamics, many of them very much of an applied nature, related to specific industrial problems. It is hoped that the Fluid Dynamics Division may serve the interest of groups with applied interest, but it is also the hope of the organizers of the group that many research physicists may be attracted by the opportunities for working on difficult, important, and challenging problems, and for making original contributions to theoretical concepts and experimental knowledge in a field of physics so important to many fields of science and industry.